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REANALYSIS OF RELATIONSHIPS AMONG EYE COLOR, AGE AND SEX IN THE COOPER'S HAWK

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ABSTRACT.—Eye color of 370 breeding Cooper's Hawks (*Accipiter cooperii*) trapped and recaptured from 1980–95 in Wisconsin was examined in relation to age and sex. In both sexes, eye color showed a change from lighter shades of yellow to darker shades of orange or red in older birds. One-yr-old males usually had light orange eyes, while 1-yr-old females typically had yellow eyes. Males ≥2 yr of age always showed darker eye color scores than females of the same relative age. Eye color cannot be used to age individual Cooper's Hawks with accuracy in Wisconsin because individual birds, especially females, show considerable variation. A test of a possible relationship between male fitness (e.g., clutch size and/or brood size) and eye color did not support the proposition that eye color serves as a signal of male quality.

KEY WORDS: *Cooper's Hawk*; Accipiter cooperii; *eye color*; *age*; *sex*.

Reanálisis de relaciónes entre color de ojo, edad, sexo en *Accipiter cooperii*

RESUMEN.—El color del ojo de 370 *Accipiter cooperii* en cría que fueron atrapados mas de una vez durante 1980–95 en Wisconsin fue examinado en relación a edad y sexo. En los dos sexos, color de ojo enseño un cambio de colores claros de amarillo y colores oscuros de naranja y rojo, mientras hembras de un año tipicamente tenian ojos amarillos. Machos ≥2 años de edad siempre enseñaban ojos oscuros comparados con hembras de la misma edad. Color de ojo no puede estar usado para indicar la edad de *Accipiter cooperii* con exactitud en Wisconsin porque pajaros individualmente, especialmente hembras, enseñaron considerable variación. Un examen de una posible relación entre la condición fisica del macho (e.g., tamaño de nidada y/o tamano de cria) y color de ojo no soporto la proposición que el color de ojo sirve como un señal de calidad de ser macho.

[Traducción de Raùl De La Garza, Jr.]

We have previously examined eye color in relation to age and sex in breeding Cooper's Hawks (*Accipiter cooperii*) in Wisconsin (Rosenfield et al. 1992). We also investigated a possible relationship between clutch size and eye color in males, as predicated on the hypothesis that male fitness might be associated with eye color because older, darker-eyed males may be better hunters and thus higher quality mates than younger, lighter-eyed males (Snyder and Snyder 1974). Snyder and Snyder also suggested that preferential mating on the basis of eye color may occur in this species.

Since 1992, we have increased our sample sizes by 36–77% for various age and sex categories of Cooper's Hawks, and 34% for clutch sizes. Reanalysis of these issues with larger samples has strengthened our earlier findings and conclusions, which have been questioned (N. Snyder, pers. comm.). We also examine eye color as a potential correlate of male fitness and hunting ability in relation to brood size at bandable age. Moreover, an update seems timely because the U.S. Bird Banding Laboratory (M. Gustafson, pers. comm.) recently asked us to comment on the validity of using our previously published eye color data to age Cooper's Hawks.

We will show that iris color, although it exhibits an age-dependent relationship, especially in males, cannot reliably predict the age of a particular bird because of variability among individuals within an age category.

STUDY AREA AND METHODS

We trapped breeding Cooper's Hawks near their nests at 114 separate nesting areas throughout Wisconsin from

1980–95 (Rosenfield and Bielefeldt 1993, 1996). We caught 370 different individuals (170 males and 200 females) and retrapped some of the same birds a total of 161 times in subsequent years. Seventy captures involved birds of known age: 1-yr-old individuals in predominately brown plumage ($N = 25$); 2-yr-old individuals (all males) with two generations of gray feathers, plus a few retained brown feathers on their rump and/or scapular areas ($N = 9$); 2–7-yr-old individuals originally marked as nestlings (Rosenfield and Bielefeldt 1992, 1996; $N = 10$); and 26 recaptures of the above individuals in later years. The remaining 461 captures involved 326 individuals of unknown initial age (ASY birds ≥2 yr of age) and 135 recaptures of these individuals (A3Y, A4Y, etc.) in subsequent years.

Eye color of captured hawks was designated as yellow, light orange, orange, dark orange or red following Rosenfield et al. (1992). Mean eye color scores for hawks in a given relative age category were determined through assignment of corresponding numerical scores of 1–5 for yellow through red eyes, respectively (Rosenfield et al. 1992).

Clutch size and brood sizes were determined by climbing to nests in mid- to late-incubation and in mid-nestling stage (ca. 16 d of age; Rosenfield et al. 1996).

Probability values were calculated using SYSTAT (Wilkinson 1992) and StatXact-Turbo (Mehta and Patel 1992). Significance was accepted at $P \leq 0.05$.

Table 1. Iris color of known-age Cooper's Hawks breeding in Wisconsin, 1980–95.

Age in Years	Eye Color Categories				
	Yellow	Light Orange	Orange	Dark Orange	Red
Males: $N = 47$ captures					
1	2	8	1	0	0
2	0	3	11	0	0
3	0	2	5	2	0
4	0	0	3	2	1
5	0	0	0	1	1
6	0	0	0	1	0
7	0	0	1	2	0
8	0	0	0	0	1
Females: $N = 23$ captures					
1	12	2	0	0	0
2	0	2	0	0	0
3	0	1	1	0	0
4	1	0	1	0	0
5	0	1	1[a]	0	0
6	0	0	1	0	0

[a] In our earlier paper (Rosenfield et al. 1992) this individual was clerically misclassified as having a dark orange eye.

Results and Discussion

In both sexes eye color showed a change from lighter shades of yellow in younger birds to darker shades of orange or red in older birds. However, 1-yr-old males had significantly darker eyes, usually light orange, than 1-yr-old females, in which the irides are usually yellow (Fisher's Exact Test, $P = 0.003$, Table 1). ASY males had significantly darker eyes than ASY females (Fisher's Exact Test, $P = 0.0005$, Table 2). Although statistical analyses of relative ages A3Y–A9Y for both sexes were prohibited by a lack of statistical independence, males always showed a markedly higher mean eye color score than females of the same relative age (Table 2). Thus, the initial difference between the sexes in eye color in yearling hawks (Table 1) not only continued, but also increased with relative age (Table 2).

Among 161 different breeding males ≥2 yr of age, none had yellow eyes and only 12% (19) had light orange eyes; the remaining birds (88%) had orange to red eyes. It appeared that few males in our population attained red eyes until ≥4 yr of age (Table 1). In relative age birds, females appeared to show lower asymptotic eye color scores than males of the same age category (3.3 vs. 4.7, Table 2). In our population, some males and females did not achieve red eyes, at least at ages up to 6–7 yr (Tables 1 and 2).

Although the iris darkens with age in both sexes, individual birds of the same age showed variation in eye color (e.g., 3-yr-old males, Table 1). Individual birds in the same eye color category also showed considerable variation in known or relative age (e.g., orange-eyed birds, especially females, Tables 1 and 2). Because of this variation, eye color could not be used to age a given individual Cooper's Hawk in our population with accuracy. Nevertheless, birds with lighter and darker extremes of eye color could be regarded as younger and older individuals, respectively, especially when an adequate sample for the population became available.

We urge banders and others to apply these results cautiously, particularly in other populations. Birds in the western U.S. differ from eastern birds in several morphological respects (Rosenfield and Bielefeldt 1993), but data on eye color in relation to age and sex are unreported for Cooper's Hawks in the west.

Because eye color is age-dependent, especially in males, it may also index the experience and foraging skills of males (Snyder and Snyder 1974). If so, older males might be higher quality mates of

Table 2. Iris color of relative-age[a] Cooper's Hawks breeding in Wisconsin, 1980–95. Numbers in parentheses equal percent.

Relative Age	Eye Color Categories						Mean Eye Color Score
	1 Yellow	2 Light Orange	3 Orange	4 Dark Orange	5 Red	Total	
Males: N = 217 captures							
ASY	0	15 (11)	57 (40)	46 (32)	24 (17)	142	3.6
A3Y	0	1	15	19	6	41	3.7
A4Y	0	0	5	5	8	18	4.2
A5Y	0	0	0	2	5	7	4.7
A6Y	0	0	0	1	5	6	
A7Y	0	0	0	1	0	1	4.8[b]
A8Y	0	0	0	0	1	1	
A9Y	0	0	0	0	1	1	
Females: N = 244 captures							
ASY	9 (5)	53 (29)	87 (47)	33 (18)	2 (1)	184	2.8
A3Y	0	9	16	5	1	31	2.9
A4Y	0	3	5	2	1	11	3.1
A5Y	0	0	6	3	0	9	3.3
A6Y	0	0	5	1	0	6	
A7Y	0	0	1	1	0	2	3.3[c]
A9Y	0	0	0	1	0	1	

[a] Relative-age birds are ASY (after-second-year) birds two or more years of age, and recaptures of these individuals (A3Y, A4Y, etc) in subsequent years.

[b,c] Values for A6Y through A9Y.

greater fitness than younger males with lighter eyes. We have proposed that clutch size may be a revealing test of male quality (Rosenfield et al. 1992) because males provide virtually all the food consumed by their mates in the preincubation period (Rosenfield et al. 1991, Rosenfield and Bielefeldt 1993). We previously tested this proposition (Rosenfield et al. 1992) and found no statistically significant difference in clutch size among eye color categories ($P > 0.05$). We reexamined this proposition with our larger sample sizes from more years (Table 3). Again, there were no significant differences in clutch sizes among eye color categories ($P = 0.85$). Excluding one yellow-eyed male, mean clutch size did not vary by more than 0.15 egg, even though the range of clutch sizes ran from 2–6 eggs. Insofar as clutch size is concerned, male age as indexed by eye color appears to be unrelated to male quality.

Table 3. Clutch size by eye color category for breeding male Cooper's Hawks in Wisconsin 1980–95.

Color Category	N	$\bar{x}$[a]	Range
Yellow	1	4.0	NA
Light orange	12	4.25	3–6
Orange	58	4.34	2–5
Dark orange	40	4.35	2–6
Red	30	4.40	2–6

[a] No significant differences in clutch sizes among male eye color categories (Kruskal-Wallis test, $P = 0.85$).

Because males continue to serve as the principal provider of food to females and young for at least the first 2 wk of nestling life (Bielefeldt et al. 1992), we also examined male eye color in relation to brood size. For this purpose, we divided breeding adults into 3 categories: (1) pairs in which both males and females were gray-plumaged birds at least 2 yr of age; (2) pairs in which 7 additional females were brown-plumaged yearlings mated to gray-plumaged males; and (3) pairs in which 7 additional males were brown-plumaged yearlings (Table 4). We partitioned pairs in this manner to allow separate investigation of pairs containing birds known to be 1 yr in age. Gray-plumaged pairs accounted for 90% of all pairs. There were no significant differences in brood sizes among male eye

Table 4. Mean brood size by eye color category for breeding male Cooper's Hawks and by age structure of mated pairs in Wisconsin, 1980–95. Number in parentheses equals sample size.

MATED PAIR AGE[a]	EYE COLOR CATEGORIES			
	LIGHT ORANGE	ORANGE	DARK ORANGE	RED
Gray Males mated to Gray Females[b]	4.00 (18)	3.46 (50)	3.63 (35)	3.92 (25)
Gray Males mated to Brown or Gray Females[b]	4.00 (18)	3.47 (53)	3.56 (39)	3.92 (25)
Brown or Gray Males mated to Brown or Gray Females[b]	3.67 (24)	3.46 (54)	3.56 (39)	3.92 (25)

[a] Gray and brown birds are those individuals ≥2 years of age and 1 year old, respectively.

[b] No significant differences in brood sizes among male eye color categories (Kruskal-Wallis Test, $P = 0.13$, $P = 0.11$, $P = 0.30$, for top, middle, and bottom rows of age categories of mated pairs, respectively).

color categories in any of these 3 groupings of pairs ($P = 0.13$–0.30). Mean brood size did not vary by more than 0.54 nestlings among male eye color categories even though brood sizes ranged from 1–5 young. Younger males with light orange eyes had mean brood sizes as large or slightly larger than older orange or dark orange-eyed males and light orange-eyed males had mean brood sizes essentially the same as red-eyed males, even though the former males were probably about 2 yr younger than the latter males (Table 1).

Therefore, we think it unlikely that eye color functions as a signal of male quality, or as a basis for female choice of mates (Snyder and Snyder 1974). Eye color need not serve as a signal of age or breeding experience in brown-plumaged yearling males, which, for example, provided 4 of the 13 males in the yellow and light orange eye color categories of clutch size.

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